14. MODEL SUPPORT ROLL BALANCE AND ROLL COUPLING

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SUMMARY

The design concepts of two specialized wind-tunnel model support mechanisms are described. The forced oscillation roll balance mechanism was designed to meet the specific requirement to measure aerodynamic forces and moments to permit determination of the damping-in-roll parameters of winged configurations. A variable-speed motor is used to oscillate the model by means of an offset crank. The oscillating motion is resisted by a torsion spring to provide a restoring torque and is attached to the section forward of the strain-gage balance. This spring action allows the model to be oscillated at a frequency for velocity resonance, whereby the mechanical spring and any aerodynamic spring balance out the model inertia. The only torque then required to oscillate the model at that particular frequency is equal to that due to aerodynamic damping. The second mechanism, a roll coupling for remotely rotating a model, was designed to invert or roll a model about its longitudinal axis when mounted for testing. The coupling utilizes a small dc gearmotor to drive an integrally designed compound planetary drive system, a potentiometer for remote readout of position, and limit switches to prevent overtravel.

INTRODUCTION

Aerodynamic research in wind tunnels requires specialized model support mechanisms. There are frequent requirements for new designs to permit determinations of aerodynamic characteristics. In response to such a requirement the forced oscillation roll balance mechanism was designed by Mr. Roy E. Sharpes. Aerodynamic testing may also be facilitated by a unique design which permits more efficient operation as provided by the roll coupling for remotely rotating a model. This roll coupling was designed by Mr. William J. Carroll.

FORCED OSCILLATION ROLL BALANCE MECHANISM

This portion of the report will discuss the design and operation of a forced oscillation roll balance mechanism to be used in the study of roll damping and other effects on models in wind-tunnel testing operations.

In figure 1 the operating position of this mechanism is shown in relation to the model and the supporting drive system in a typical tunnel installation. In most installations this balance mechanism will be located as shown, within the fuselage portion of the model, where no tunnel blockage nor airflow disturbance will be created. The drive system shown is typical of two drive systems presently being used to operate oscillating pitch balance mechanisms in tunnels

at Langley Research Center. This oscillating roll balance mechanism has been designed to be interchangeable with the existing oscillating pitch balances. These mechanisms are readily detachable from the drive systems and the models and may therefore be quickly interchanged, as desired, to adapt to either oscillating pitch or oscillating roll operation of the models with a minimum of tunnel shut-down time.

The drive system shown supplies power to the mechanism through the continuous rotation of a drive shaft motivated by a variable-speed, variable-voltage, 2-hp dc electric motor. This mechanism then converts this continuous rotational input movement into a reversing, or oscillating, roll output movement. The input and output movements are maintained about a common axial center line.

One unique feature of this mechanism is that it converts a high torsional continuous revolving input movement into a high torsional oscillating roll output movement, in a very limited space, with a minimum of moving parts. This mechanism has an overall length of about 42.5 centimeters (16.75 inches) and a maximum diameter of about 7.3 centimeters (2.875 inches).

The design and operation of this mechanism will now be explained referring to figure 2.

The means for converting the continuous rotational input movement into an oscillating roll output movement is accomplished by means of a converter yoke. One end of the yoke has a forked sliding connection with a bearing block pivoted on a stationary pin. See figure 2, SECT. D-D. The other end of the yoke has a forked sliding connection with a bearing block pivoted on a drive pin projecting from the part to be oscillated. The yoke has a central bearing to receive an offset crank, driven by the input rotational power drive. As the yoke is actuated by the crank, the yoke making sliding contacts with the bearing blocks will pivot about the stationary pin at one end and will move the drive pin at the other end. Since the drive pin can only move on a radius about its supporting bearings, which are mounted concentrically with the input drive, then the input and output rotational movements will be maintained about a common center line. See figure 2, SECT. A-A and SECT. D-D. The cranking motion, through the actuation of the yoke, will then produce one cycle of oscillation for each revolution of the drive crank. The angle of oscillation is determined by the throw of the crank and is limited by the operating space available for the yoke. Stationary body structure must be provided to bypass the yoke to support the oscillating body, including the forward end of the mechanism to which the model is attached.

Maintaining a minimum overall diameter of this mechanism is very important since the space available for it in most models is extremely limited. Since the loading on models can be extremely high, it is very important to maintain maximum loading capacity. The design feature of keeping the input and output rotational movements about a common center line is imperative in attainment of maximum loading capacity with minimum overall diameter.

A balance beam system is machined into the oscillating body near the forward end to which strain gages are attached to measure the various forces on the model. See figure 2, PLAN VIEW & SECT. A-A. The temperature-control heater

bands maintain uniform temperatures at both ends of the balance beams to insure more accurate strain-gage readings.

The oscillating motion in each direction of roll is resisted by a mechanical spring. The torsion spring is attached to the oscillating body forward of the strain-gage balance section and provides a restoring torque. See figure 2, SECT. A-A. This spring action allows the model to be oscillated at a frequency for velocity resonance, whereby the mechanical spring plus any aerodynamic spring balances out the model inertia. The only torque then required to oscillate the model at that particular frequency is equal to that due to aerodynamic damping. This damping effect of the model can thus be measured through the strain-gage system attached to the balance beams. The torsional spring has been designed to be easily interchangeable with other springs sized as required for optimum operation with various size models.

The portion to which the model is attached is supported on needle bearings to allow it to oscillate freely. A thrust bearing is also provided to take the end loading on the model. These bearings are secured to the supporting shaft portion by retainer rings, as shown in figure 2, SECT. A-A. In order to assemble and retain the oscillating body on the supporting bearings, the housing has been made in two parts. Each part has tapered mating engagements that are securely clamped together by an external nut, thereby effecting a rigid joint.

This roll balance mechanism has been used successfully in conducting tests of a model of the space shuttle orbiter in the Unitary Tunnel at Langley Research Center. The balance oscillating roll angle was $2\frac{1}{2}^{\circ}$ in each direction. Data were recorded at 9 to 11 cycles per second; Mach numbers of 1.6 to 4.6 and pitch angles of 0° to 30°. The oscillating roll balance assembly is shown in figure 3 and the balance parts are shown in figure 4.

A ROLL COUPLING FOR REMOTELY ROTATING A MODEL

The purpose of this portion of the report is to describe a remotely controlled mechanism that will invert or roll a model about its longitudinal axis when mounted for testing.

It is the general practice in most wind tunnels to investigate all models both in an upright and an inverted position to establish the magnitude of the flow-angle correction. At other times it may be desired to test at various roll angles, models of missiles, launch vehicles, pressure instrumented models, or models with survey rakes. For facilities that only have model supports with provision for angular motion in one direction, the roll coupling can be used to obtain angles in a second plane (e.g., if pitch data are obtained ordinarily, yaw data would be easily obtained from roll and angle-of-attack settings).

In the past to roll or invert a model it was necessary to cut power and stop operation of the tunnel, open the hatch or door to the test section and, with the proper tools, disconnect and relocate the model support sting to the next angular position required. These steps resulted in a considerable loss of time, labor, and electrical energy.

Figure 5 shows a solid coupling connecting a typical model sting to the main support system. The primary design requirement was to provide a coupling of approximately the same size and shape for aerodynamic considcrations and, in addition, to provide the roll mode of operation. Thus the name, roll coupling. So that this new coupling (fig. 6) could fit to the existing stings and other model support equipment the two tapered ends were not changed. To house the motor and drive system as shown in figure 7, the overall length was changed from 35.56 centimeters (14.00 inches) to 43.18 centimeters (17.00 inches) and the diameter from 10.16 centimeters (4.00 inches) to 12.70 centimeters (5.00 inches). A comparison between the two couplings is shown in figures 5 and 6.

The two major parts, the outer housing, which is fixed to the main model support, and the rotating end or output shaft are machined from heat-treated 17-4PH stainless steel. This output shaft is mounted on two tapered roller bearings and has one end machined with internal gear teeth that mesh with the planet pinions of a compound planetary drive system. Each of these four pinions has teeth machined on one end that mesh with and drive this output shaft. On the other end of the pinion are teeth that mesh with the internal gear teeth of the ring gear that is pressed into the housing. These pinions are spaced equally in the planetary system with no frame nor cage being used to support them. Each pinion is therefore free to float or adjust to any misalignment or irregularity that may be in the system. The driving pinion and shaft of the planetary system are machined integrally. This shaft has a bore through the center and is concentric with the output shaft to allow passageway for the balance leads and other electrical wires that may come from the model. Also machined integrally with this shaft is a spur gear that mates with the initial gear of the transmission system that receives its power from a small commercial dc gearmotor. A potentiometer is geared to the output shaft to transmit the position or amount of roll. Limit switches are also included as a safety precaution to prevent overtravel.

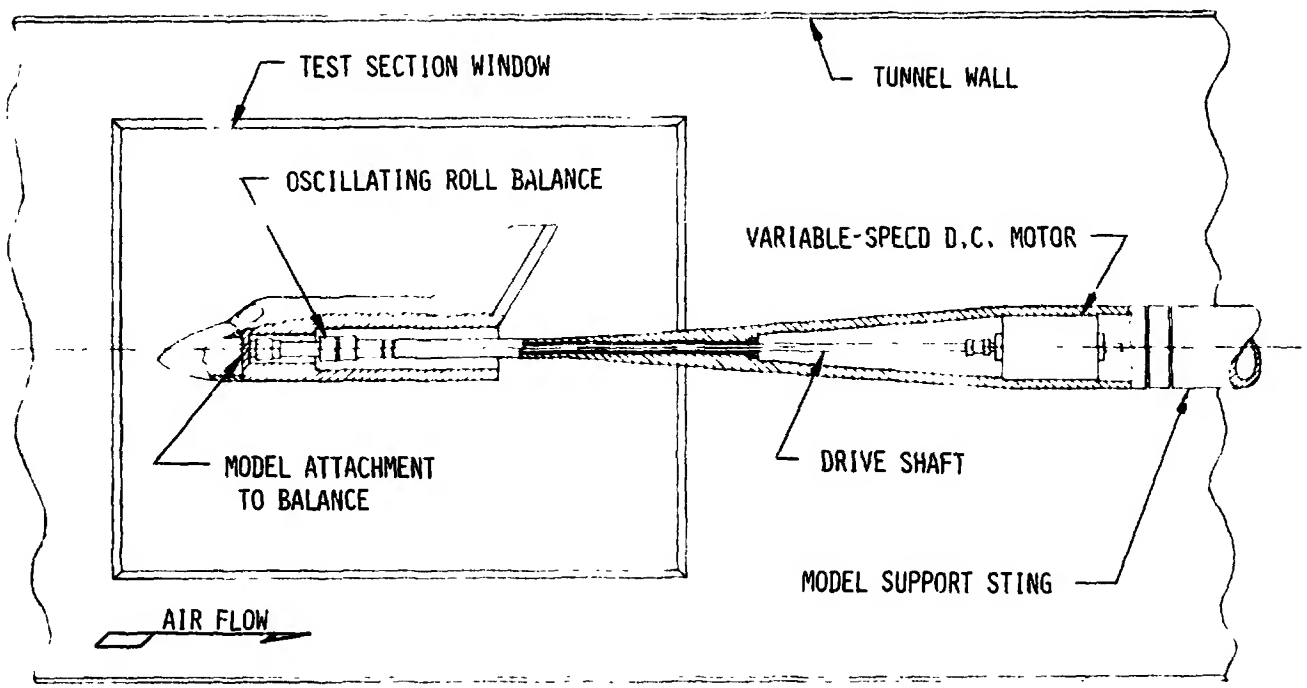

Figure 1.- Typical wind-tunnel installation of roll balance mechanism.

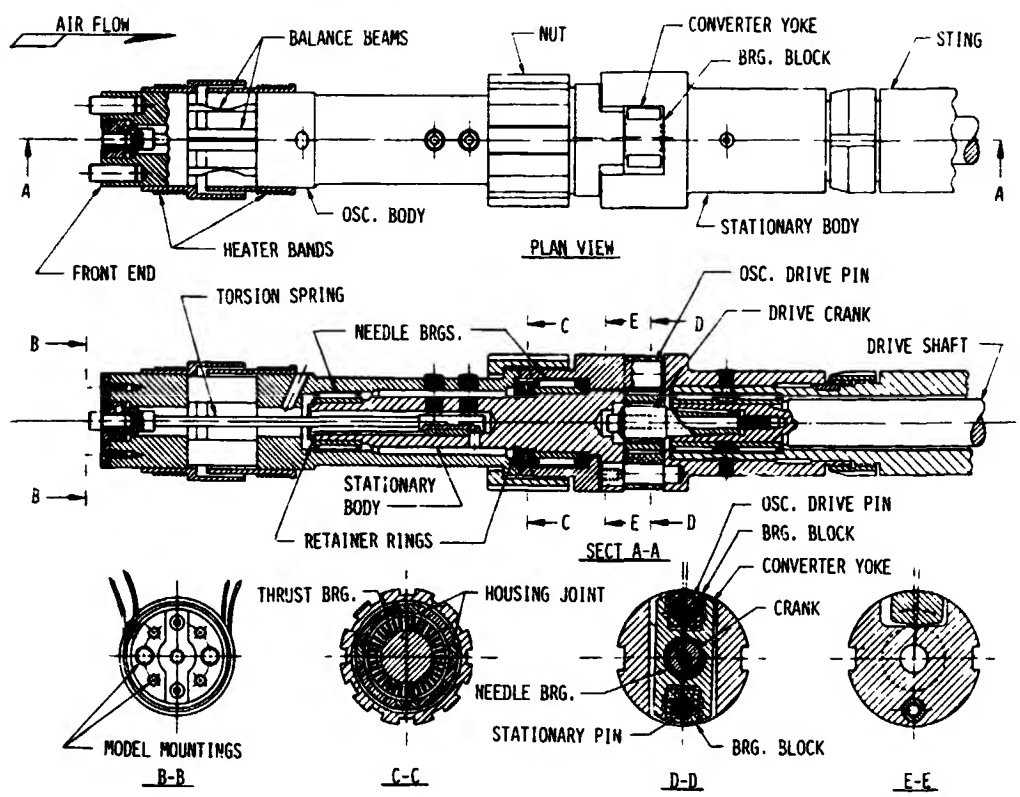

Figure 2.- Forced oscillation roll balance mechanism.

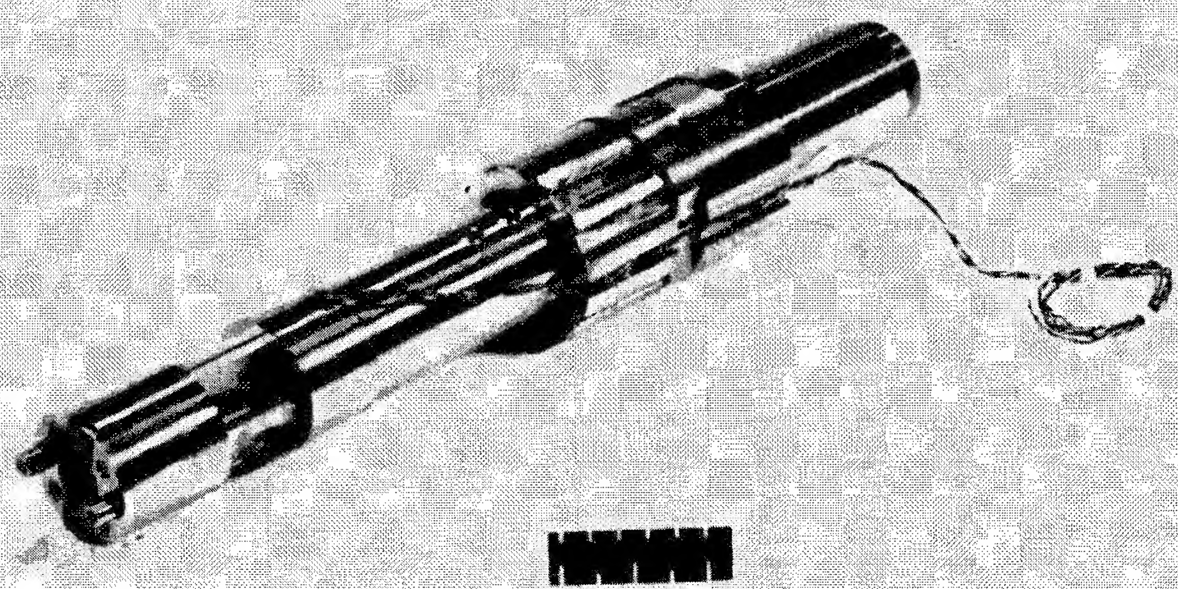

Figure 3.- Oscillating roll balance assembly.

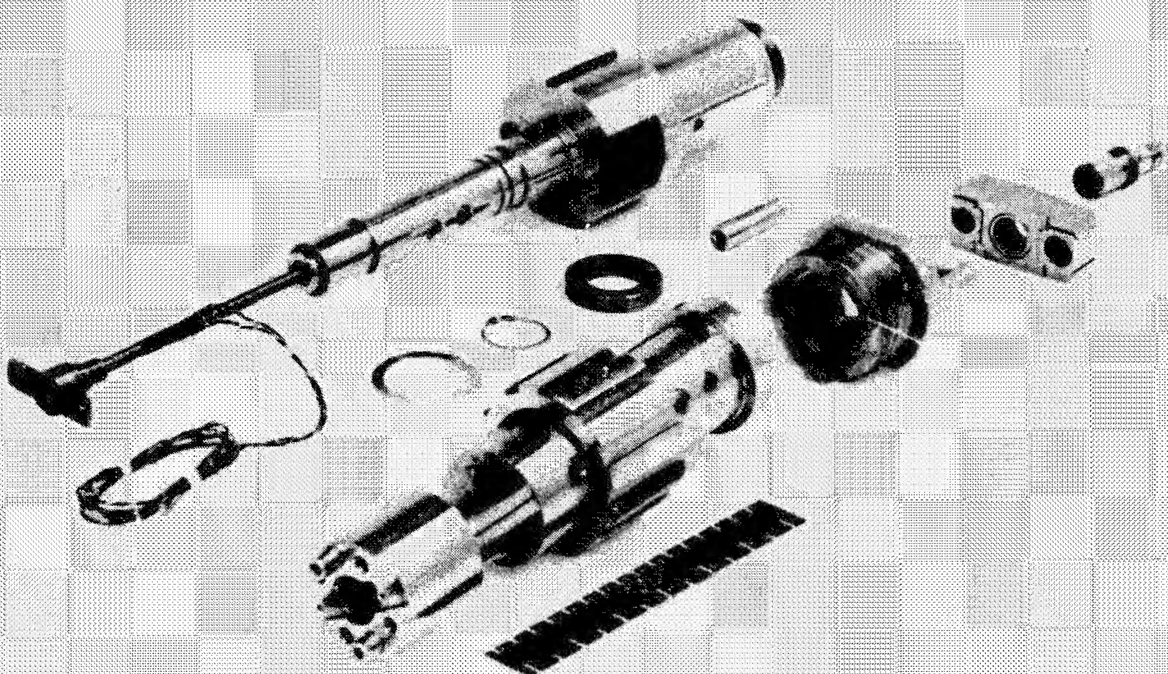

Figure 4. - Components of roll balance assembly.

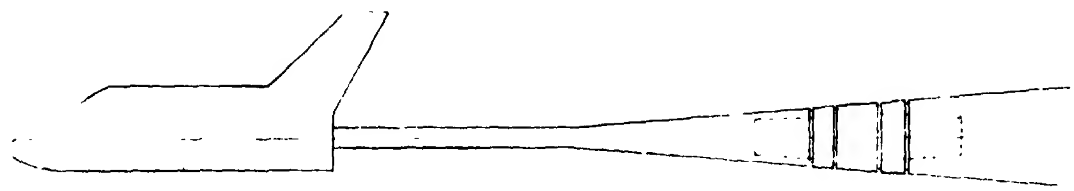

Figure 5.- Solid-coupling configuration.

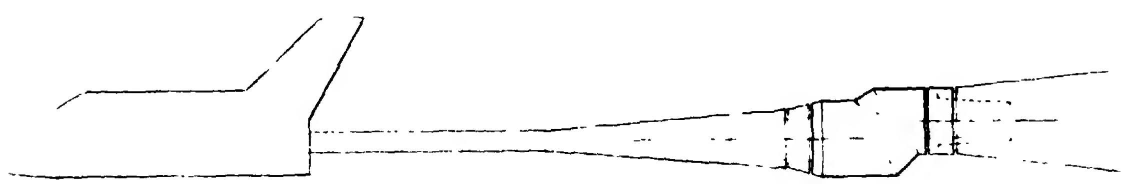

Figure 6.- Roll-coupling configuration.

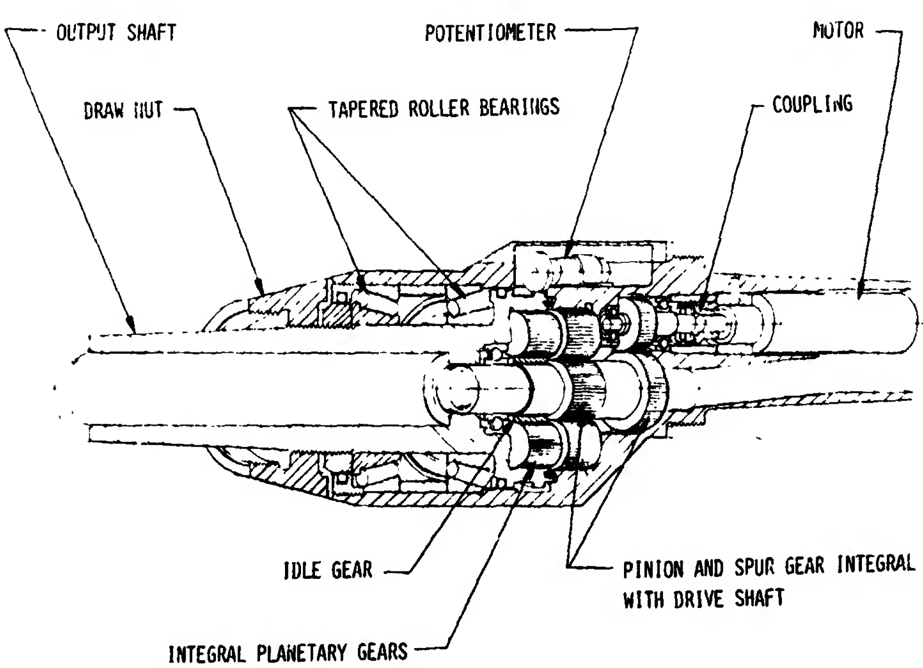

Figure 7.- Cutaway assembly of roll coupling.